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Collecting and Interpreting Patient Dose Data

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IAEA Training Course on Medical Physics in Diagnostic Radiology
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Collecting & interpreting patient dose data
Patient dose audit methods

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Scope and purpose of dose audits

- Dose audits are usually conducted
  - To get an idea of radiological practice
  - To compare doses applied to those typically applied in other countries/hospitals
  - To estimate collective doses to the population from medical use of radiation
    - Does necessitate a reliable assessment of examination numbers, what is often more difficult than assessing dose values
  - To define DRLs
  - To verify DRLs und eventually update values and examinations
  - To check compliance with DRLs
  - To locate institutions which need help in optimization
  - As part of a quality control program
  - To improve imaging in healthcare
  - To create dose awareness

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Average doses – typical doses

- A typical dose for a standard examination is the dose a “standard patient” will most likely receive
- Definition of a standard patient is necessary
- Average dose (= average calculated from patient doses collected in the audit) from need not be dose to a standard patient
- → concordance of collectives
- This should be kept in mind when comparing doses from different regions/member states

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Patient dose audits

- Internal audits
  - Systematic determination of patient doses for standard examinations in a single hospital/radiological office
  - To be used internally for optimisation and justification
  - Usually carried out by an internal auditor (medical physicist, etc.)
  - If there is no internal capacity (equipment, manpower) the audit can be carried out or supported by external expert
  - → **internal audit is understood in a way, that the data from the audit is for internal use**, the audit itself may be performed by or in close cooperation with an external person

- External/regional audits
  - e.g., audit covering a member state, a province of a member state, or a geographical region (European dose audit, e.g.)
  - Dose audit is performed by external auditor
  - This auditor may be from a regulatory body
  - May rely on data from internal audits

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Internal dose audits

- Determination of patient doses for typical standard examinations and procedures should be performed regularly
  - Only for standard procedures? What about high dose procedures, that are difficult to standardize?
  - Determination of individual versus “average” dose
- Experience with external audits show, that in many cases where unusually high patient doses are used, users are not aware of their typical doses
  - → dose assessment creates dose awareness
- Knowing the doses applied is the key to optimization

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Internal dose audits

- Internal dose audits should be orientated on dose reference (guidance) levels (BSS)
- Dose should not be regarded irrespective of image quality – optimally dose audit would go hand in hand with image quality audit if applicable
- Interpretation of dose audit results and feedback to clinicians is crucial

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Dose audit methodology

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Dose to phantoms or patient doses

- TRS 457 (CoP) describes dosimetry in diagnostic radiology with phantoms and patients
- In dose audits, can phantoms be used?
  - Depends on the reason why the dose audit is carried out
  - Depends, whether it is an internal or external audit

- CT: Doses are actually defined in a phantom (C_W, "CTDI", and $P_{KL,CT}$, "DLP") but from patients' scans → they are regarded as patient doses
  - Phantom doses are doses with a phantom used to simulate the patient to drive AEC → phantom used determines dose level by it's attenuation

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Phantoms

- *"Dose assessments with phantoms cannot provide a direct estimate of the average dose for a given patient population … it is important therefore that any measurements with phantoms are supplemented by measurements made on patients"* (CoP, Appendix VII)

- Comment: need not be measurements on patients, any method to derive patient dose data is o.k. (actually, calculation of K_i from patient exposure data would be preferred)
- Only exemption: mammography, here MGD determined with a phantom is advised

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Phantoms

- Phantoms can only be used for external audits if the scope of the audit is to compare doses between institutions/member states/regions . . .
- Phantom doses are different to patient doses and should only be compared to phantom doses
- In internal audits patient doses are measured, therefore phantom doses are not advised

- Exemptions:
  - Mammography
  - In case Dose Reference Levels or doses to which local doses are to be compared for the examination of interest are specified as dose to phantom

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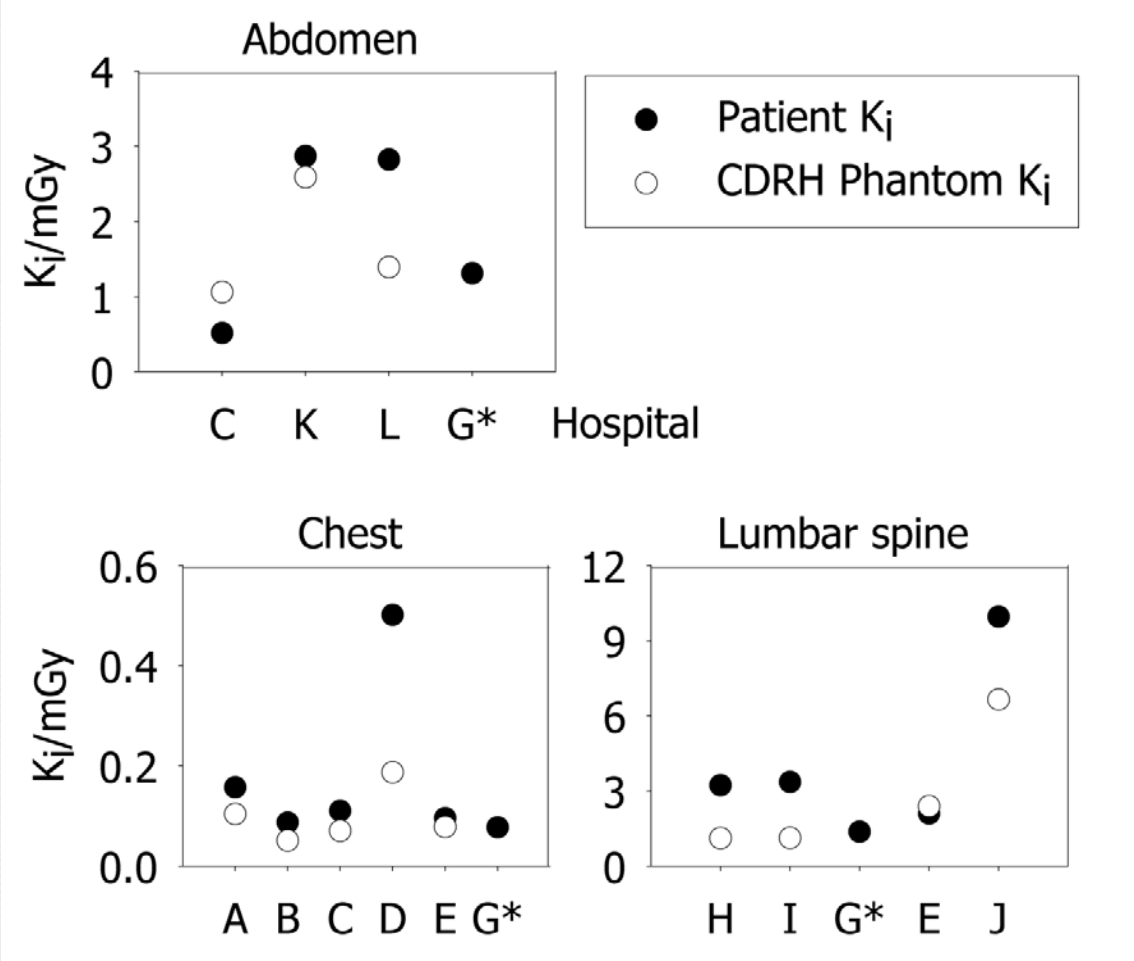
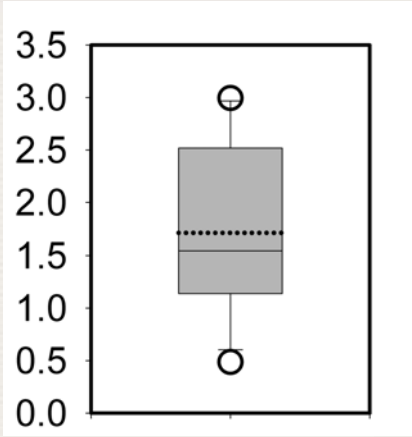
Phantom versus patient doses





Patient to phantom dose

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Mean values or quartiles

- Evaluation methodology depends on survey
- Internal audit (one hospital or even one x-ray room)
  - Question to be answered: what is the “typical” dose to a patient undergoing examination/intervention X?
  - Typically, a small numbers of patients/examinations (10 to 100) will be available, all taken with the same equipment
- Regional audit
  - Many different hospitals participated
  - Different types of equipment
  - Question to be answered: which dose do we usually work with? What is the dose our hospitals should be able to produce images with, that they find of good diagnostic quality?
- → data evaluation (later)

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Carrying out a patient dose audit

- Select equipment / examination(s)
- Select methodology
- Ensure you have
  - staff (med phys + radiology)
  - dosimetry equipment
  - traceable calibration
- Plan audit & allow plenty of time
  - Time frame of internal audit: typically several months
  - Time frame for external (regional audit): typically one year
    - Time for data collection: several months
    - Plan plenty of time for support to clinics – do not assume they are familiar with assisting in a dose survey, especially if you plan a survey in CT and fluoroscopy/interventional

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Quality Assurance of Dose Data

- Exam specification
- Data sampling
  - Patient inclusion/exclusion criteria
    - Especially important in interventional procedures
- Plausibility checks of data
- Feedback & analysis of results

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Exam Specification

- Terminology may not be consistent between departments, or may be inexact
- Can only compare ‘like with like’
- Common problem areas
  - Barium enema/small bowel enema
  - Nephrostogram/nephrostomy
  - CT lung cancer staging (inc/not inc liver)

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Sample Sizes

- Patient dose data has inherent uncertainties which increase with exam complexity
- Minimum number of patients 10 - 50
- Variations in patient size must also be accounted for
  - Restrict weight range (can reduce sample size by up to a half)
  - Correct data for patient size

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Size Correction (Newcastle method)

- Changes in dose due primarily to automatic increase in exposure factors
- Dependant on AEC program/set-up
- Test by exposing increasing thicknesses of tissue equivalent slabs & recording DAP
- Carried out for different fluoroscopy & acquisition modes

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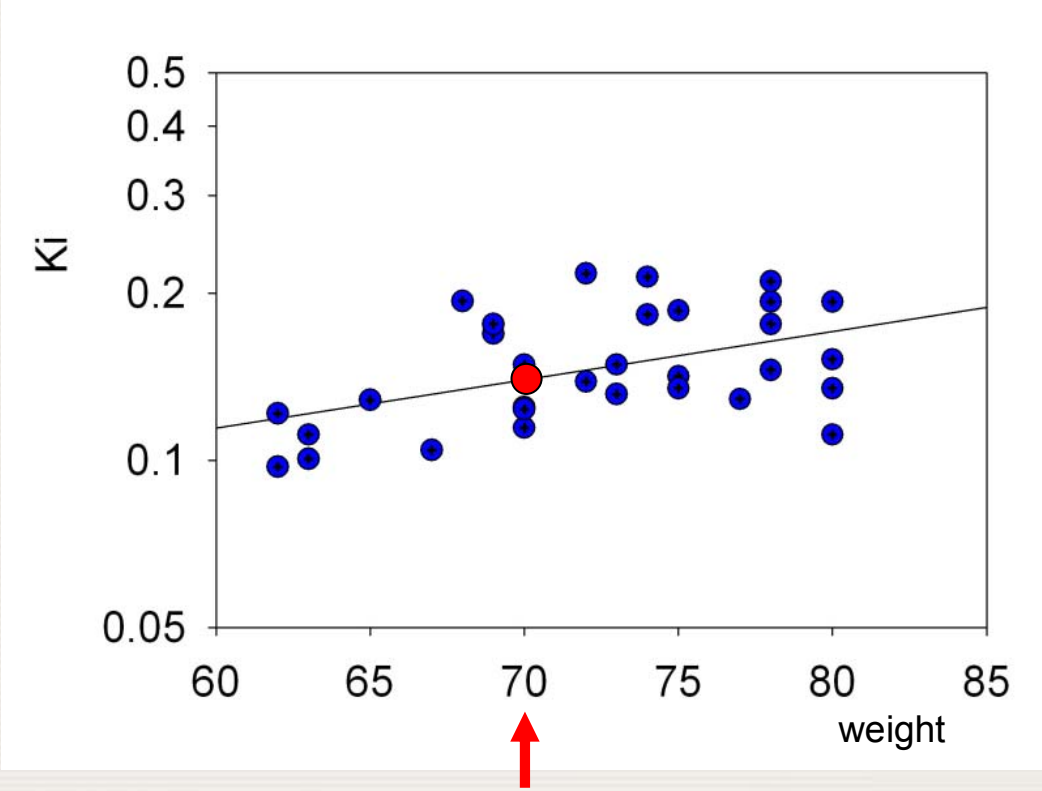
Size correction (Vienna method)

- Exponential regression
- Evaluation of regression curve at weight of “average patient”
- Easier, but estimation of patient-to-patient variation is a little more difficult



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Feedback of Data

- Collecting data only 1 stage of process
- Regular feedback required, preferably with DRLs etc for comparison
- Comparisons with other departments, including relevant technique factors useful
- Patient dose data may be linked with equipment QA measurements
  - Optimally automatically recorded to a data base or within the DICOM header of the image in case of digital images

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Data evaluation and interpretation

Internal (local) audit

Question to be answered: what is the “typical” dose to a patient undergoing examination/intervention X?

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Dose to the average patient

- Determination of typical dose
- Estimation of patient-to-patient variation
- Estimation of combined uncertainty budget

- The more data on each patient exposure has been collected, the easier optimization and interpretation may be later
  - Better, to collect all relevant technique factors, not only these necessary to calculate dose

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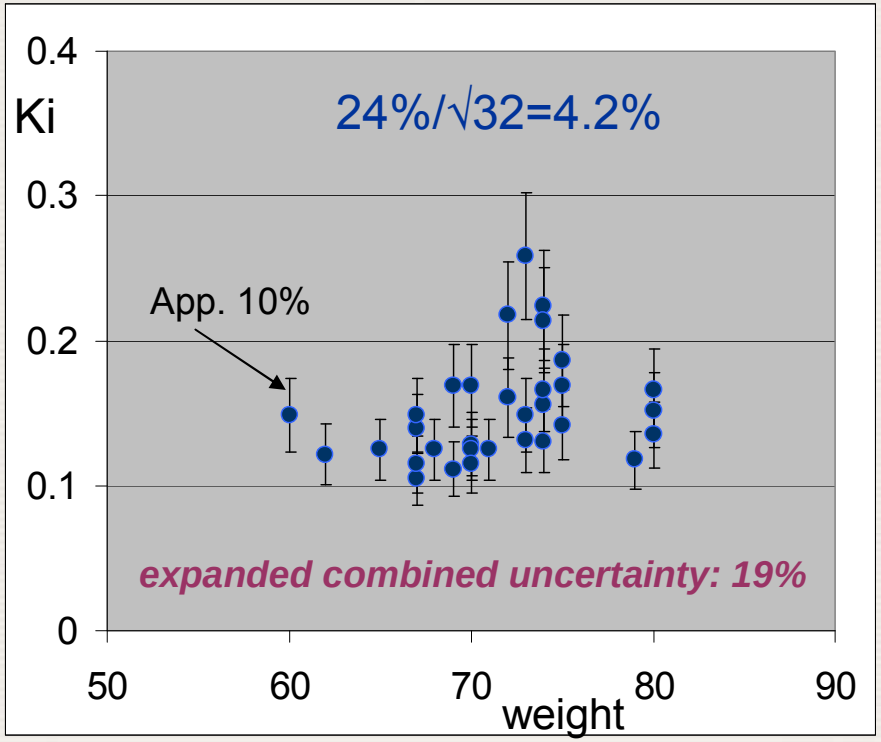
Uncertainties and dose variations

Example: chest



- The more complex the examination/intervention, the larger patient to patient variations are expected
- Every dose data point has an uncertainty
- Should be considered when comparing doses to doses of others, or reference levels

Number of patient dose data necessary depends on dose variation

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Example “chest” is from the uncertainty tutorial
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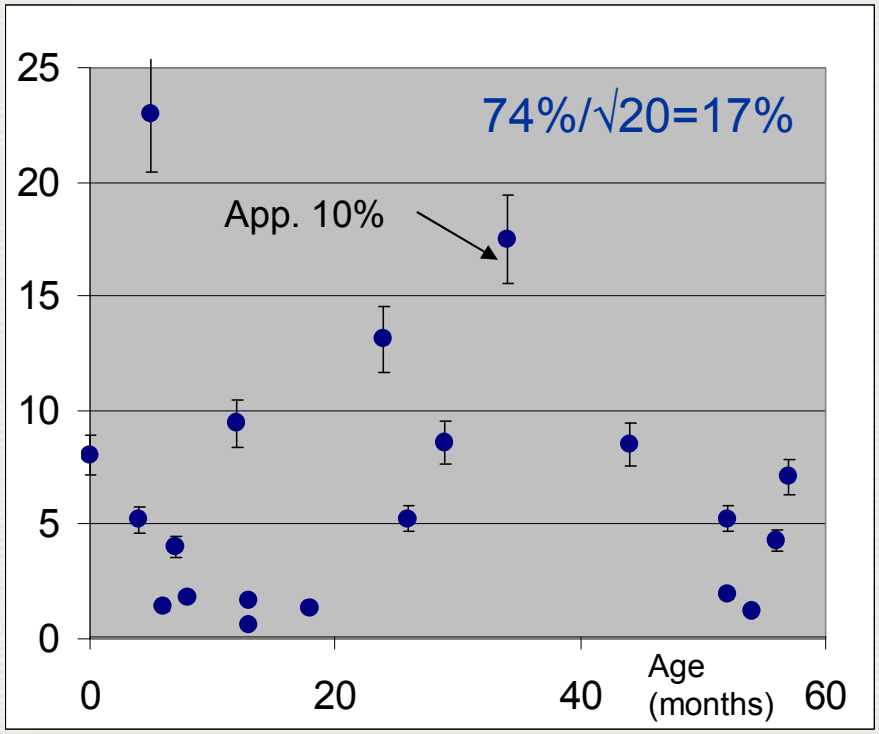
Uncertainties and dose variations



expanded combined uncertainty: ~40%

- Example: MCU in children
  - Data shows 1 ½ orders of magnitude variation
- Does it make sense to consider dose – age relationship in this data?
- Number of patient dose data necessary
  depends on dose variation → more patients necessary here
- How many for <25% combined expanded uncertainty?
  - Approx. 5% in 1 sigma for std of mean from patient to patient variation → 200 patients
  - With 200 patients, a trend of dose with age should be visible → more sophisticated statistical analysis → actually, less patient data needed
- Can reference levels be applied for individual examinations?

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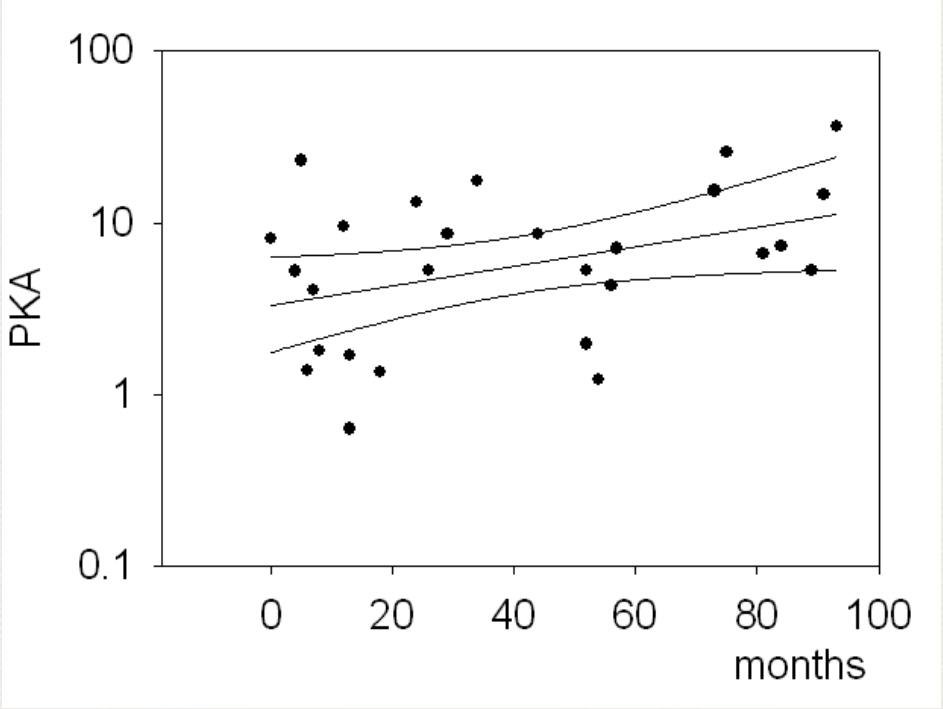
Same example, more data

- Estimation of uncertainties using confidence limits
- Approximately same results on uncertainties as before
- See also uncertainty tutorial



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Interpretation

- How do the doses compare to reference levels?
  - If they exceed the reference values, is this significant
    - Uncertainty budget!
  - Still, if doses are close to DRLs, optimization might still be indicated
    - Remember, 3rd quartiles are not optimum values
    - histograms & inter-quartile distances
- Is the patient to patient variation within an acceptable range? Is there a systematic deviation, e.g. between day/night or do same teams use significantly higher doses than others
  - → identification of training needs for staff

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Data evaluation and interpretation

External (regional) audit:

Question to be answered: which dose do we usually work with? What is the dose our hospitals should be able to produce images with, that they find of good diagnostic quality?

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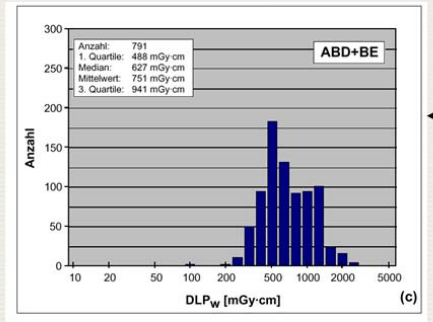
Dose distributions and histograms

- Distributions of average patient doses
- Provide a good understanding of dose range applied
- Help identify institutions needing support in optimizing technique factors

Typical dose distributions

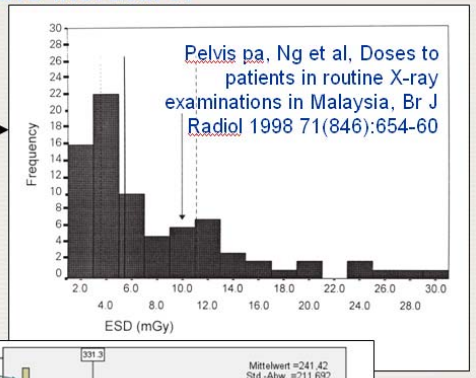
". . . even now, order of magnitude variations in patient doses are possible for the same diagnostic examinations " CoP, Appendix VII

- Numerous examples can be found in the literature:

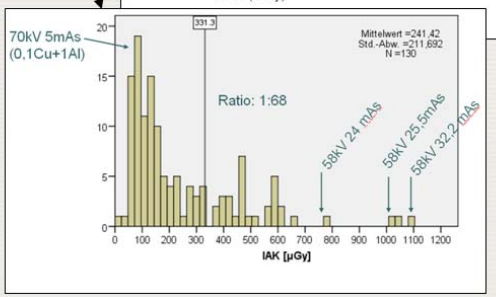


CT of abdomen and Pelvis, from Galanski et al. 1999
CT Expositionspraxis in der Bundesrep. Deutschland

Individual patients



Pelvis pa, Ng et al, Doses to patients in routine X-ray examinations in Malaysia, Br J Radiol 1998 71(846):654-60



Skull x-ray of 1year olds in Austria, Billinger and Homolka, 2008

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Quartiles

- Calculate dose to the standard (“average”) patient for every institution, for every examination
  - If institutions report dose values for one examination from different department (e.g., radiology dept., trauma, ICU) it may be a good ides to evaluate these separately since the doses are sometimes considerably different. Even if they are not, this is valuable information
- Check validity of data reported
  - This may be tricky
  - Recommended: if any doubts visit institution and assist local contact person
- Check if examinations reported are really comparable
  - Different definitions of “standard examinations” may have been used
- Calculate dose quartiles
- Provide a comparison of average doses from every institution/department/room with reference doses and quartiles
- Provide an interpretation of this comparison
- In case urgent need for optimization is found in an institution you may wand to offer medical physics assistance

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- Thanks!

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